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Pollination ecology of three *Ipomoea* species, *I. cairica*, *I. marginata* and *I. trilobata* (Convolvulaceae)

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ABSTRACT

Three *Ipomoea* species, *I. cairica, I. marginata* and *I. triloba* included in this study are hermaphroditic climbing or twining species, the first two species are perennials while the last one is an annual. In all three species, the flowers present stigma far above the stamens to ensure pollination, especially cross-pollination. *I. cairica* and *I. triloba* are pollinated by honey bees and stingless bees, and *I. marginata* by honey bees and a papilionid butterfly. *I. cairica* and *I. triloba* are self-incompatible and obligately outcrossing while *I. triloba* is suspected to be self-compatible but it appears to be primarily cross-pollinating as there is only rare to low fruit and seed set rate in these species. In all three species, fruit is a capsule which either dehisces or pops open while still attached to parent plant to release seeds which are disseminated either by wind or by water according to the ecological situation. *I. cairica* and *I. marginata* being perennials have the ability to propagate also by vegetative mode while *I. triloba* being an annual does not have the ability to propagate by vegetative mode.

Key words:
Ipomoea cairica, I. marginata, I. triloba, hermaphroditism, entomophily, obligate out-crossing, anemochory, hydrochory

1. INTRODUCTION

In Convolvulaceae family, majority of the species are herbaceous twiners and others are either shrubs or trees (Steiner et al. 2006). Species in this family are primarily melittophilous although they are also reports of sphingophily, ornithophily and chiropterophily (Willmott and Burquez 1996; Austin 1997). The genus *Ipomoea* consists of about 500 species of trees, shrubs, twining and trailing herbs distributed in tropical parts of the world (Austin 2004). A few species of this genus have been studied for their pollination ecology. Maimoni-Rodella and Yanagizawa (2007) reported melittophily in *Ipomoea cairica, I. grandifolia* and *I. nil*. Hull-Sanders and Eubanks (2005) reported mixed mating system, melittophily, sphingophily and psychophily in *I. hederacea* var. *integriuscula*. Suvarna Raju et al. (2011) reported mixed mating system, sphingophily and partial melittophily in *I. tuba*. With this backdrop, three species of *Ipomoea, I. cairica*, *I. marginata* and *I.*

triloba have been studied for their pollination ecology to know whether these species also display mixed mating system and melittophily.

2. MATERIALS AND METHODS

Three species of *Ipomoea, I. cairica* (L.) Sweet, *I. marginata* (Desr.) Manitz and *I. triloba* L. growing in wild open areas on Andhra University campus and in Adavivarm area of western Visakhapatnam city of Andhra Pradesh were selected for study during June 2020-October 2021. The study included the investigation of flowering season, floral morphology, and floral configuration in relation to pollination mode, sexual system, pollinators and their foraging behavior, fruit and seed aspects. All these aspects were observed in the field to under the pollination ecology of all the three species.

3. RESULTS AND DISCUSSION

***Ipomoea cairica*:**

I. cairica is believed to be native to tropical Africa and Asia but now naturalized throughout Australia, North, Central and South America, the Carribean and also on many islands across the Indo-Pacific ocean region (Staples 2020). In India, it grows throughout the country, especially in tropical and sub-tropical regions. It is a vigorous fast growing perennial climber with tuberous roots. It propagates by stem fragments and seed. It spreads easily and out-competes the local flora by invading the space by climbing and shadowing the co-occurring plants. It grows throughout the year in wet areas while it is seasonal in occurrence in semi-dry and dry areas (Figure 1a). The flowers are either solitary or few-flowered born on axillary pedunculate cymose inflorescences; they are pedicellate, trumpet-shaped, white and bisexual (Figure 1b,c). As the flowers are entirely white in colour, this is treated as variety *alba* in this plant species. The calyx has 5 free, obtuse to acute shaped sepals of which 2 are small, placed in outside while the remaining 3 are long and placed inside. The corolla is tubular with five fused petals. The stamens are 5 with 2 long and 3 short ones with basally pubescent filaments and epipetalous in placement. The pistil consists of a glabrous ovate ovary with 2 carpels imbibed in nectariferous disc, slender white glabrous style tipped with a bi-lobed papillate and capitates stigma which is placed far above the position of anthers. Individual flowers secrete nectar to the extent of 6 µl which is collected around the ovary. The nectar sugar concentration stands at or above 40% according to changing ambient temperature throughout the day. Galetto and Bernardello (2004) reported that *I. cairica* produces hexose-rich nectar with more glucose than fructose, which is preferred by bees possessing short-tongues (Baker and Baker 1983). In line with this, different workers reported that *I. cairica* is visited by bees, flies and butterflies (Anonymous Report), carpenter bees (Jia et al. 2007) and *Ceratina* and Halictid bees (Maimoni-Rodella and Yanagizawa 2007). In this study also, *I. cairica* is visited and pollinated by honey bees (*Apis dorsata, A. cerana* and *A. florea*) and stingless bees (*Trigona iridipennis* – Figure 1d) during day time, especially at 10:00-14:00 h. All these bees collect both nectar and pollen as the flowers provide easy access to these floral rewards. The placement of stigma far beyond the height of anthers appears to be an adaptation for facilitating and maximizing cross-pollination over self-pollination. Maimoni-Rodella et al. (1982) reported that *I. cairica* is an obligate outcrosser as it does not use spontaneous selfing for fruit set. Jia et al. (2007) reported that *I. cairica* is self-incompatible and fruit and viable seed production occurs through cross-pollination only. In this study, it is found that *I. cairica* flowers close back by late afternoon, which provides opportunity for spontaneous autogamy but rare fruit set evidenced in the study area indicates that this plant species does not use autogamy for fruit set indicating that it is self-compatible and an obligate out-crosser. Rare fruit set in open pollinations is also reported in *I. cairica* by Tarbej (2017). Fruit is a sub-globose 4-valved capsule which produces 1-4 blackish, slightly 3-angled seeds with smooth surface interspersed with dense tufts of long silky hairs. It is initially green and turns brown when mature; then it pops up to open to free the seeds which are then dispersed by wind in dry areas and by water in wet areas. Since fruit set is rare in *I. cairica*, this plant species propagates mostly by vegetative method through stem fragments (Tarbej 2017). Therefore, *I. cairica* is able to invade only by stem fragments and the seed produced through sexual mode enables the plant to maintain genetic variation and occupy different ecological habitats in order to extend its distribution range, especially in tropical regions.

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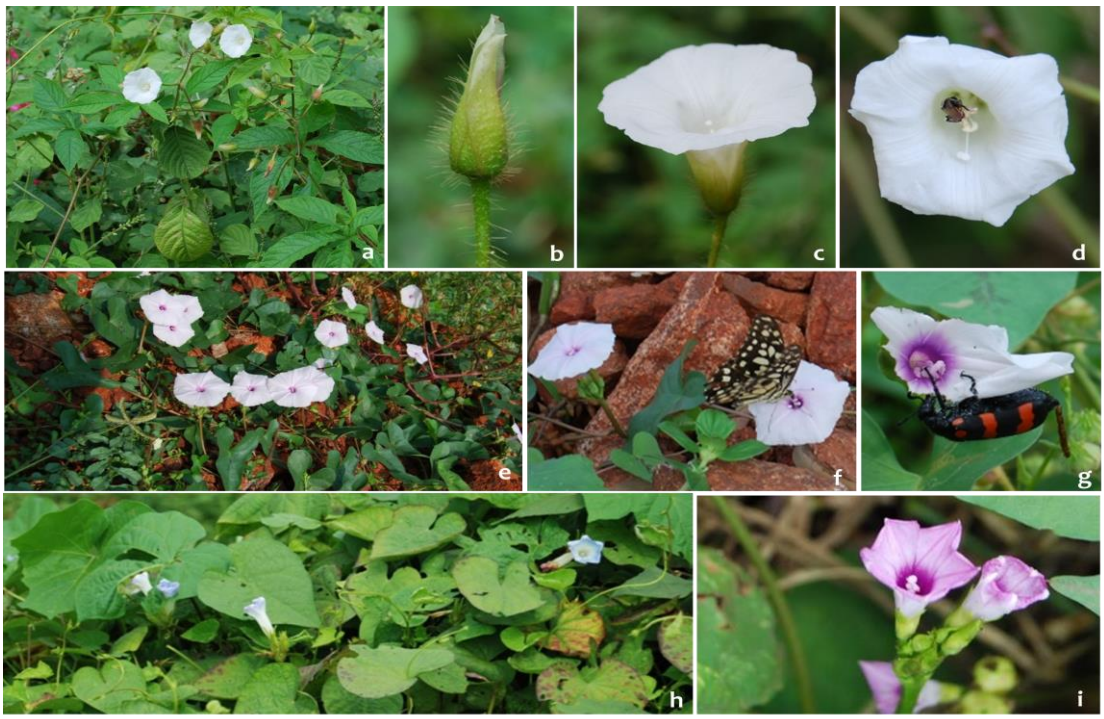

Figure 1. ***Ipomoea cairica:*** a. Habit – flowering, b. Mature bud, c. Flower, d. *Trigona iridipennis* collecting nectar; ***Ipomoea marginata***: e. Habit – in flowering, f. Papilionid butterfly, *Papilio demoleus* collecting nectar, g. *Mylabris phalerata* feeding on the corolla; ***Ipomoea triloba***: h. White variety, i. Purple variety.

Ipomoea marginata:

It is a perennial herb with a stout root and twining stems. It grows well in coastal, waste lands and rocky habitats. The plant flourishes well during wet season and sparse growth in other seasons only if the soil has the required level of soil moisture (Figure 1e). The flowers are pedicellate, erect, whitish purple, salver-form and bisexual; they are born either solitary or in few-flowered pedunculate cymes which arise from leaf axils. Mature buds open during early morning hours. The calyx has five ovate to elliptic glabrous lobes of which 3 inner ones are longer than the 2 outer ones. The corolla is whitish purple with a darker purple colored center; it is tubular throughout. The stamens are 5 with unequal filiform filaments covered with soft hairs at the base and at the other end terminated with elliptic anthers which are sagittate at base and the pollen grains are echinate. The pistil consists of a globose, glabrous bicarpellary ovary with 4 ovules, filiform style and globose bi-lobed stigma. Nectar is secreted around the ovary during anthesis. The flowers attract three species of honey bees, namely, *Apis dorsata, A. cerana* and *A. florea*, and also a papilionidae butterfly, *Papilio demoleus* (Figure 1f). The honey bees visit the flowers for nectar and pollen collection during day time with more foraging visits during 10:00-14:00 h while the butterfly visits the flower for nectar collection during 08:00-13:00 h. The foraging activity of these insects invariably effects pollination; the placement of stigma beyond the height of anthers facilitates cross-pollination if the forager is pollen-laden due to its previous visit to other flowers of other individual plants. The bagged and tagged flowers did not fruit at all indicating that the flowers are not self-pollinating and hence spontaneous autogamy is not functional. The flowers close back in early evening hours, the situation of which could effect autogamy but it is not functional. This is further substantiated by the low fruit set rate evidenced in field conditions. The floral mechanism, breeding system and low natural fruit set indicates that *I. marginata* is an obligate-outcrosser and vector-dependent as evidenced in case of *I. cairica*. The study finds that the blister beetle, *Mylabris phalerata* (Figure 1g) is a voracious consumer of corolla, stamens and stigma due to their delicate nature and also could be due to high palatability. Its feeding activity is an important contributing factor for reducing the fruit set rate in open-pollinations. Fruit is a globose, glabrous capsule with 1-4 hairy brownish angled seeds; the mature and dry fruits pop up to release seeds which in turn are carried away by wind if the ambient environment is dry and fall down in parental sites if ambient environment is humid. Further, the seeds disperse by water during rainy season. Therefore, *I. marginata* is hermaphroditic, obligate outcrosser, entomophilous, anemochorous and hydrochorous.

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Ipomoea triloba:

It is a native of tropical Americas but it is widely distributed in warm regions of the world. It grows well in sandy soils, open waste lands and cultivated areas (Adams et al. 1972). It is a fast-growing herbaceous annual herb with thin stems and petiolate heart-shaped 3-lobed leaves. The flowers are bell-shaped and variable in color; white variety and purple variety have been found to occur in the study area. The white variety is completely white without any shades of purple color (Figure 1h) while purple variety is completely purple with deep red-violet throat (Figure 1i). The flowers are born in leaf axils; they are either solitary or in small clustered cymes. The sepals are 5, lanceolate and occur in two unequal whorls, the outer whorl has two short sepals and the inner whorl has 3 long sepals. The corolla tube is funnel-shaped with 5-lobes apically. The stamens are 5 with different lengths, included and remain inside the corolla tube; the anthers produce minutely echinate pollen grains. The pistil consists of a conical 2-4 celled densely pubescent 4-ovuled ovary basally surrounded by a white nectary, filiform style with a 2-lobed stigma.

In this study, it is found that the flowers of *I. triloba* white and purple variety open during 06:00 to 08:00. Schlising (1970) also noted that *I. triloba* flowers are fully open before 08:00 h and they are visited by bees and wasps until 11:00 h by which time the flower wilting occurred. Ordetx (1949) noted that *I. triloba* is an important plant in honey production in Cuba and other Central American countries, which indicates that honey bees have pollination role in this species. In this study, both varieties of *I. triloba* flowers were foraged by honey bees and stingless bees only for nectar and pollen collection from 07:00 to 15.00 h. The flower structure is such that the stigma is placed beyond the height of stamens to facilitate the brushing of pollen with great ease onto the stigma when the pollen-laden forager enters from another flower to seek forage by crawling deep into the corolla tube. Such a placement of sex organs in the flower appears to be evolved to promote cross-pollination because there is no scope to preclude self-pollination. The flowers of both varieties showed signs of fading and slow folding/twisting of corolla lobes from 14:00 h onwards and closed completely enclosing the sex organs placed inside. The flower closure event purportedly evolved to provide an opportunity for spontaneous autogamy. Jones (1968) reported that *I. triloba* is self-fertile and cross-pollination is not necessary for seed set. Schlising (1970) felt that in *I. triloba*, cross-pollination is advantageous, even if it is not necessary for good seed set. In this tudy, it is not clear whether *I. triloba* is self-compatible or –incompatible but the fruit set rate is low in open-pollinations as many flowers fail to set fruit. This situation indicates that *I. triloba* is primarily cross-pollinating despite keeping the option open for self-pollination either by spontaneous autogamy or vect0r-mediated selfing. Fruit is a small globose 4-valved capsule with a persistent style surrounded basally by a persistent calyx; it contains 1-4 sub-globose, hard, shiny, dark brown seeds. Mature dry fruits dehisce while still on the parent plant to disperse seeds which are then driven by wind during dry ambient weather and by water during rainy season. The study indicates that *I. triloba* is a hermaphroditic, melittophilous, anemochorous and hydrochorous species.

4. CONCLUSIONS

Three *Ipomoea* species, *I. cairica*, *I. marginata* and *I. triloba* included in this study are climbing or twining species, the first two species are perennials while the last one is an annual. All the three species grow throughout the year depending on the soil moisture content. The flowers are bisexual, nectar-producing, and born either solitary or as small clusters which arise from leaf axils. The flowers are completely white and represent var. *alba* in *I. cairica* and white with dark purple corolla throat in *I. marginata*. In *I. triloba*, the white flowers without any shades of purple color represent white variety and purple flowers with deep red-violet throat represent purple variety. In all three species, the flowers present stigma far above the stamens to ensure pollination, especially cross-pollination. *I. cairica* and *I. triloba* are pollinated by honey bees and stingless bees, and *I. marginata* by honey bees and a papilionid butterfly. *I. cairica* and *I. triloba* are self-incompatible and obligately outcrossing while *I. triloba* is suspected to be self-compatible but it appears to be primarily cross-pollinating as fruit and seed set rates are rare or stand at low level in these species. In all three species, fruit is a capsule which either dehisces or pops open while still attached to parent plant to release seeds which are disseminated either by wind or by water according to the ecological situation. *I. cairica* and *I. marginata* being perennials have the ability to propagate also by vegetative mode while *I. triloba* being an annual does not have the ability to propagate by vegetative mode.

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Authors contributions:

All authors contributed equally.

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Conflicts of interests

The authors declare that there are no conflicts of interests.

Data and materials availability

All data associated with this study are present in the paper.

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